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Characteristics of Pilot- and Full-Scale Hazardous Waste Incinerator Ash

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16. ABSTRACT

This review encompasses ash characterization data from 16 different hazardous waste incinerators, both pilot- and full-scale, treating a variety of waste streams. Its focus is on 14 volatile organic compounds, 18 semivolatile organics, and 13 metals for which analyses were most frequently performed. Included are results of analyses of ash leachate prepared according to EPA's Toxicity Characteristic Leaching Procedure (TCLP).

The most frequently detected metals in the ash analyses (as indicated by the fraction of analyses that were above detection limits) were chromium, zinc, copper, nickel, lead, arsenic, and silver. The most frequently detected volatile organic compounds were toluene, xylene, trichloroethene, acetone, methylene chloride, and 1,1,1-trichloroethane. Predominant semi-volatile organics were bis (2-ethyl hexyl) phthalate, naphthalene, phenol, di-n-butyl phthalate and pyrene. Metals were generally detected with greater frequency than organic compounds.

Because this review is based on different incinerators treating a variety of wastes under different conditions, it is difficult to isolate the effects of specific variables (i.e., incinerator operating conditions, waste feed characteristics) on ash quality. It is recommended that dedicated parametric testing be conducted to determine such effects.

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CHARACTERISTICS OF PILOT-AND FULL-SCALE HAZARDOUS WASTE INCINERATOR ASH

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INTRODUCTION

Incineration of hazardous waste has been the subject of U.S. EPA research since 1974. E. Timothy Oppelt, now Director of the U.S. EPA Risk Reduction Engineering Laboratory (RREL), recently examined the current state of knowledge regarding hazardous waste incineration. While all effluents from hazardous waste incinerators are important, Oppelt found that the greatest interest and the majority of testing has been on stack emissions, and that information on incinerator ash was limited. The available data on ash did suggest that very small amounts of residual organic compounds can remain in incinerator ash and that, while the levels of metals in ash vary widely, ash generally does not exhibit RCRA toxicity characteristics. (1)

Oppelt's conclusions on ash were based primarily upon two studies. The first involved tests of several incinerators as part of the incineration Regulatory Impact Analysis (RIA) program. (2) The second study focused on characterization of ash and air pollution control device (APCD) residues from ten additional incinerators. (3) Over the past two years, additional tests have been conducted in which the characteristics of incinerator ash were determined.

The intent of this paper is to review the combination of information from past and more recent studies to provide a larger picture of organic and metal concentrations in hazardous waste incinerator ash and its leachates.

APPROACH

The sources of ash characterization information on which this paper is based include the following:

- U.S. EPA Regulatory Impact Analysis (RIA) Program (2)
- Ten-incinerator Residuals-Characterization Test Program (3)
- RCRA Best Demonstrated Available Technology (BDAT) Incineration Tests (4-10)
- BDAT Incineration of CERCLA Synthetic Soils (11)
- Superfund Innovative Technology Evaluation (SITE) Demonstration Testing (12)

This review encompasses test data from 16 different incinerators (8 rotary kiln, 6 fixed hearth, 1 fluidized bed, and 1 liquid injection) treating a variety of waste streams. Two of the rotary kiln incinerators tested were pilot-scale; the other 14

incinerators were full-scale. The pilot-scale incinerators (one at EPA's Combustion Research Facility; the other operated under contract to EPA at The John Zink Co. Test Facility) were used in independent tests of several listed wastes. As a result, there are 23 different waste feed/ incinerator combinations incorporated in this review.

Seven of the incinerators practiced water-quenching of ash. In one of these incinerators, ash samples were taken prior to quenching. As a result, 17 of the 23 analyses discussed herein were performed on dry ash with the remainder having been subjected to quenching. Bottom ash represents all but two of the ash samples; in the case of the liquid injection- and fluidized bed-incinerators, control device ash (fly ash) was analyzed.

The composition of waste feeds varied widely across the tests and included the following RCRA waste codes: D001, D002, D006-D009, F001-F003, F005, F024, K001, K011, K013, K014, K024, K037, K086, K087, and U002.

The analytes for ash from each of the tests included a variety of organics and metals, with the list of each differing from test to test. This study focused on those organics and metals for which analyses were most frequently performed. This narrowed the scope to 14 volatile organics, 18 semivolatile organics, and 13 metals.

RESULTS/DISCUSSION

Tables 1, 3, and 5 summarize the results of ash analyses for metals, volatile organics and semivolatile organics, respectively. Tables 2, 4, and 6 summarize the results of analyses of ash leachate (prepared according to the Toxicity Characteristic Leaching Procedure [TCLP] described in Appendix I to 40 CFR, Part 268) for metals, volatile organics and semivolatile organics, respectively.

The most frequently detected metals in the ash analyses (as indicated by the fraction of analyses that were above detection limits) were chromium (100%), zinc (100%), copper (95%), nickel (90%), lead (86%), arsenic (76%), and silver (58%). Most of the same metals also predominated in the ash leachate analyses but with somewhat lesser frequencies: zinc (89%); copper (89%); nickel (80%); chromium (67%); and selenium (50%). In terms of the average magnitude of measured values, zinc, copper, lead, nickel, and chromium were most significant in the ash analyses. These same metals, along with cadmium, predominated in the ash leachate.

Volatile organics were detected with lesser frequencies in the ash analyses; toluene (38%), xylene (25%), trichloroethene (21%), acetone (20%), methylene chloride (13%) and 1,1,1-trichloroethane (13%) were the compounds most often detected. Compounds were generally detected with higher frequencies in the ash leachate, with methylene chloride (69%), acetone (63%), toluene (62%), benzene (60%), chloroform (50%) and xylene (50%)

predominating. Toluene and xylene were among the more significant organic compounds in terms of magnitude in both the ash and leachate analyses. Also of significant magnitude were 1,1,1-trichloroethane and trichloroethene in the ash analyses, and methylene chloride, acetone and carbon disulfide in the leachate.

Semivolatile organics were detected in the ash analyses with frequencies similar to those for volatile organics; bis (2-ethyl hexyl) phthalate (39%), naphthalene (28%), phenol (24%), di-n-butyl phthalate (20%) and phenanthrene (20%) were the compounds most often detected. Compounds were generally detected with lesser frequencies in the leachate analyses; phenol (38%) and bis (2-ethyl hexyl) phthalate (15%) were the only semivolatile organics detected in more than one leachate analysis. In terms of the average magnitude of measured values, phenol, bis (2-ethyl hexyl) phthalate, di-n-butyl phthalate, and naphthalene were the more significant compounds (for which more than one measurement above detection limits existed) in the ash analyses.

Table 1. Metals - Analysis (mg/kg)

Metal	# of Analyses	# of Analyses Above DL (a)	Range of DL's (b)	Range of Measurements	Avg. of Measured Values (c)
Antimony	19	8	0.8-400	2.0-240	48
Arsenic	21	16	1.0-100	0.4-46	13
Beryllium	19	3	0.5-7	0.71-2.6	0.92
Cadmium	21	8	0.53-2.0	1.0-130	22
Chromium	21	21	-	1.1-660	140
Copper	19	18	4.0	2.0-6900	960
Lead	21	18	1.0-21	0.96-3100	580
Mercury	18	4	0.001-200	0.1-3.3	0.91
Nickel	21	19	7.5-10	3.0-7300	470
Selenium	17	8	1.0-40	2.8-19	8.8
Silver	19	11	0.83-32	1.1-120	23
Thallium	19	6	1.0-180	3.0-7.0	5.0
Zinc	19	19	-	1.8-21000	1600
	254	159			

Table 2. Metals - TCLP (mg/L) (d)

Metal	# of Analyses (e)	# of Analyses Above DL (a)	Range of DL's (b)	Range of Measurements	Avg. of Measured Values (c)
Antimony	18	8	0.01-0.3	0.02-0.36	0.18
Arsenic	21	8	0.001-1.5	0.019-0.54	0.095
Beryllium	18	2	0.001-0.01	0.0014-0.003	0.0022
Cadmium	21	4	0.004-0.02	0.0084-2.0	0.56
Chromium	21	14	0.004-0.045	0.015-2.7	0.31
Copper	19	17	0.009-0.05	0.02-16	2.7
Lead	21	9	0.01-0.5	0.021-29.3	3.3
Mercury	18	2	0.0002-0.0025	0.0003-0.2	0.1
Nickel	20	16	0.01-0.1	0.02-13	1.9
Selenium	16	8	0.01-1.5	0.02-1.4	0.21
Silver	18	2	0.007-0.06	0.05-0.13	0.09
Thallium	17	2	0.015-0.93	0.1-0.18	0.14
Zinc	19	17	0.03	0.06-300	28
	247	109			

(a) DL = Detection Limit
(b) Range of detection limits for those tests in which the compound was not detected.
(c) Average of measurements which were above the detection limit
(d) TCLP = Toxicity Characteristic Leaching Procedure
(e) Two of the leachate samples were prepared using the EP toxicity procedure, for each of the metals except copper and zinc

The overall frequencies of detection (% of total analyses found above detection limits) were as follows: ash analyses (metals [63%], volatiles [14%], and semivolatiles [14%]); leachate analyses (metals [44%], volatiles [31%], and semi-volatiles [6%]).

For reference purposes, EPA treatment standards for organic compounds in leachates of RCRA wastes F001-F005 (spent solvents) are shown in Table 4. Of the seven organic compounds for which

Table 1. Volatile Organics - Analysis (mg/kg)

Compound	# of Analyses	# of Analyses Above DL (a)	Range of DL's (b)	Range of Measurements	Avg. of Measured Values (c)
Acetone	10	2	0.25-250	0.4-0.5	0.45
Benzene	13	1	0.01-100	1.8	1.8
Carbon disulfide	13	1	0.5-100	2.8	2.8
Chlorobenzene	16	1	0.006-100	2.5	2.5
Chloroform	10	0	0.01-100	-	-
Chloromethane	13	1	0.5-100	1.7	1.7
1,2 Dichloroethane	8	1	0.003-100	0.01	0.01
trans 1,2-dichloroethylene	13	1	0.5-100	1.1	1.1
1,1,1 Trichloroethane	15	2	0.01-100	3.7-6.2	5.0
Trichloroethene	14	3	0.01-100	2.5-5.4	4.4
Methylene chloride	16	2	0.003-250	0.004-0.78	0.39
Styrene	16	1	0.003-100	4.3	4.3
Toluene	16	6	0.025-100	0.19-120	25.1
Xylene	16	4	0.005-100	0.006-15	4.1
	189	26			

Table 4. Volatile Organics - TCLP (ug/L) (d)

Compound	# of Analyses	# of Analyses Above DL (a)	Range of DL's (b)	Range of Measurements	Avg. of Measured Values (c)	F001-F005 Treatment Standards (e)
Acetone	8	5	5.0-250	6.0-950	340	590
Benzene	10	6	0.2-50	2.0-13	5.5	-
Carbon disulfide	13	2	0.2-50	4.0-900	450	4810
Chlorobenzene	13	1	0.2-50	2.0	2.0	50
Chloroform	8	4	0.2-50	3.0-17	9.3	-
Chloromethane	13	0	0.2-50	-	-	-
1,2 Dichloroethane	6	2	0.2-50	3.0-8.0	5.5	-
trans-1,2-dichloroethylene	13	0	0.2-50	-	-	-
1,1,1 Trichloroethane	13	3	0.2-50	3.0-77	34	410
Trichloroethene	12	2	0.2-50	7.0-17	12	91
Methylene chloride	13	9	5.0-250	14-550	130	960
Styrene	12	1	0.2-10	62	62	-
Toluene	13	8	0.2-50	6.0-1700	350	330
Xylene	12	6	0.2-10	2.4-80	43	150
	159	49				

(a) DL = Detection Limit
(b) Range of detection limits for those tests in which the compound was not detected.
(c) Average of measurements which were above the detection limit
(d) TCLP = Toxicity Characteristic Leaching Procedure
(e) F001-F005 treatment standards of 40 CFR, Part 268.41

Table 5. Semivolatile Organics - Analysis (mg/kg)

Compound	# of Analyses	# of Analyses Above DL (a)	Range of DL's (b)	Range of Measurements	Avg. of Measured Values (c)
Acenaphthene	16	1	0.01-2.5	0.26	0.26
Aniline	14	0	0.01-5.0	-	-
Anthracene	17	1	0.01-2.5	0.15	0.15
1,2,4 Trichloro-benzene	14	1	0.01-2.5	10.0	10.0
Chrysene	15	1	0.01-2.5	0.2	0.2
Fluoranthene	16	2	0.01-2.5	0.23-0.61	0.42
Benzo(b)fluor-anthene	16	1	0.01-2.5	0.2	0.2
Naphthalene	18	5	0.01-2.5	0.17-41	4.1
Phenanthrene	16	3	0.01-2.5	0.48-1.3	0.89
Phenol	17	4	0.01-2.5	0.35-400	100
4-Nitrophenol	14	0	0.01-12.5	-	-
Benzyl butyl phthalate	16	3	0.01-2.5	0.28-7.0	4.1
Bis(2-ethyl hexyl)phthal	18	7	0.01-2.5	0.31-500	94
Di-n-butyl phthalate	15	3	0.01-2.5	0.41-39	16
Diethyl phthal	15	0	0.01-2.5	-	-
Dimethyl phthal	14	1	0.01-2.5	31	31
Di-n-octyl phthalate	15	2	0.01-2.5	0.76-2.5	1.6
Pyrene	15	1	0.01-2.5	0.34-1.3	0.77
	281	38			

Table 6. Semivolatile Organics - TCLP (ug/L)

Compound	# of Analyses	# of Analyses Above DL (a)	Range of DL's (b)	Range of Measurements	Avg. of Measured Values (c)
Acenaphthene	13	0	2-50	-	-
Aniline	13	1	2-100	20	20
Anthracene	13	0	2-50	-	-
1,2,4 Trichloro-benzene	12	1	2-50	10	10
Chrysene	13	0	2-50	-	-
Fluoranthene	13	0	2-50	-	-
Benzo(b)fluor-anthene	13	0	2-50	-	-
Naphthalene	13	1	2-50	8.0	8.0
Phenanthrene	13	0	2-50	-	-
Phenol	13	5	2-50	6-1800	410
4-Nitrophenol	13	1	2-250	90	90
Benzyl butyl phthalate	13	0	2-50	-	-
Bis(2-ethyl hexyl)phthal	13	2	2-50	24-56	40
Di-n-butyl phthalate	13	1	2-50	14	14
Diethyl phthal	13	1	2-50	6.0	6.0
Dimethyl phthal	13	1	2-50	580	580
Di-n-octyl phthalate	13	0	2-50	-	-
Pyrene	13	0	2-50	-	-
	233	14			

(a) DL = Detection Limit
(b) Range of detection limits for those tests in which the compound was not detected.
(c) Average of measurements which were above the detection limit
(d) TCLP = Toxicity Characteristic Leaching Procedure

standards are given, toluene is the only compound found in the data presented with an average leachate value in excess of the spent solvent standard.

CONCLUSIONS

The purpose of this paper was to present a summary of available data on the characteristics of hazardous waste incinerator ash. On the basis of this information, general comments relative to the toxicity of ash may be made. However, because the information is based on observations of different facilities incinerating different wastes under many different conditions, it is not possible to make conclusive statements on the effect of specific factors on ash quality.

A number of factors, including waste feed concentration of analytes, temperature and O2 concentration in the combustion chamber, throughput rate, charge size and frequency (for batch feed), ash quenching practice, waste feed matrix, and combustion chamber type can be expected to have an effect on ash quality. In order to make conclusions on the effect of these factors, designed experiments in which variables are controlled are warranted.

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